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Descriptive study of production factors affecting performance traits in growing-finishing pigs in Spain

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Abstract

The objective of this study was to build up a data set including productive performance and production factors data of growing-finishing (GF) pigs in Spain in order to perform a representative and reliable description of the traits of Spanish growing-finishing pig industry. Data from 764 batches from 452 farms belonging to nine companies (1,157,212 pigs) were collected between 2008 and 2010 through a survey including five parts: general, facilities, feeding, health status and performance. Most studied farms had only GF pigs on their facilities (94.7%), produced "industrial" pigs (86.7%), had entire male and female (59.5%) and Pietrain-sired pigs (70.0%), housed between 13-20 pigs per pen (87.2%), had ≥ 50% of slatted floor (70%), single-space dry feeder (54.0%), nipple drinker (88.7%) and automatic ventilation systems (71.2%). A 75.0% of the farms used three feeding phases using mainly pelleted diets (91.0%), 61.3% performed three or more antibiotic treatments and 36.5% obtained water from the public supply. Continuous variables studied had the following average values: number of pigs placed per batch, 1,515 pigs; initial and final body weight, 19.0 and 108 kg; length of GF period, 136 days; culling rate, 1.4%; barn occupation, 99.7%; feed intake per pig and fattening cycle, 244 kg; daily gain, 0.657 kg; feed conversion ratio, 2.77 kg kg^{-1} and mortality rate, 4.3%. Data reflecting the practical situation of the Spanish growing and finishing pig production and it may contribute to develop new strategies in order to improve the productive and economic efficiency of GF pig units.

Additional key words: facilities; feeding; production indexes; Spanish pig production.

Introduction

In 2010 Spain produced approximately 3.4 million tons of pork, being the second and fourth EU (Eurostat, 2010) and world (Faostat, 2010) producer respectively. Pig production accounted for approximately 35.2% of the final livestock production and 11.4% of the final agricultural production. Catalonia is the main producing region accounting for 27.5% of the total pig production in Spain followed by Aragón (21.8%) and Castilla y León (8.8%) (MAGRAMA, 2012). According to SIP Consultors (2011), the growing-finishing (GF) period is the most expensive component of pig production and accounts for approximately 69% the costs in Spanish pork production. Some of the main factors affecting productivity of GF pigs are genetics, commercial type of pig produced, feed and feeding management, facilities (especially barn conditions) and health status (Losinger, 1998; Maes *et al.*, 2004; Oliveira *et al.*, 2009). Several papers have quantified the effect of these factors on performance, especially concerning genetics, commercial type, feeding management (Gispert

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Abbreviations used: ADG (average daily gain); ADURFAT (average duration of the fattening period); BO (barn occupation); CR (culling rate); FBW (final body weight); FCR (feed conversion ratio); GF (growing-finishing); IBW (initial body weight); MORT (mortality rate); NPP (number of pigs placed); TDURFAT (total duration of the fattening period); TFI (total feed intake).

This work has 1 Supplementary Table that does not appear in the printed article but that accompany the paper online.

et al., 2007; Niemi *et al.*, 2010) and health status (Martínez *et al.*, 2009). However, there is less research on the effects of facilities and general management on GF pig productivity in commercial conditions. In Spain, Oliveira *et al.* (2009) studied the effect of several factors on mortality and feed intake in GF farms from one integration company located in Galicia. However, using data from only one company which is located in a region with a limited pig inventory may limit the applicability of these results.

Thus, the objective of this study was to create a dataset of GF pig farms from several companies in Spain in order to have representative information of the present characteristics of the Spanish GF pig industry. Furthermore, the relationships among performance indexes and production factors were also described in a bivariate analysis.

Material and methods

Data collection

Data were collected between July 2008 and July 2010 from a total of 452 GF farms [see questionnaire in Suppl. Table 1 (pdf)]. Recruited farms were integrated in nine out of the twenty five biggest pig companies in Spain, accounting for about 20% of the national GF pig production. Most of the farms were located in three Spanish regions, Aragón (44%), Cataluña (35%) and Castilla y León (18%), while a small group (3%) was located in other regions: Navarra, La Rioja and Valencia. One to three batches of animals per farm were included in the database adding up to a total of 764 batches. Batch was defined as a group of pigs from around 15-27 kg that entered a GF unit and was raised until they reached a suitable weight for slaughter. A total of 1,157,212 pigs, accounting for about 1.5% of the total number of pigs slaughtered in Spain during the two-year period, were used to evaluate the variability of both production factors and productive performance. Production factors were registered at farm level and productive performance was recorded at batch level.

All variables to be registered were selected after an extensive literature review. All variables had been proven to be variation factors in the final output of GF pig farms. On farm, data were collected through a survey model prepared by the research team in agreement with field veterinarians and pig companies participating in the study. The survey was divided in five sections as indicated in Table 1; four of these sections were related to production factors and one was related to productive performance.

Regarding productive performance records, also included in Table 1, number of pigs placed (NPP) corresponded to the number of pigs which entered the unit in each batch. Averages initial and final body weight (IBW and FBW, kg pig^{-1}) were defined as the total batch weight divided by the number of pigs in each batch when entering the GF unit and prior to transportation to the slaughter facility respectively. Total feed intake (TFI, kg pig^{-1}) was calculated from the total feed delivered to each batch minus the amount of feed remaining in the silos when each batch was slaughtered, divided by the number of marketed pigs. Average daily gain (ADG) was calculated the as the difference between IBW and FBW divided by the number of days between these measures. Feed conversion ratio (FCR, kg kg^{-1}) was obtained dividing the total feed delivered to each batch (kg) by the difference between the total kilograms of pigs sent to slaughter and the total kilograms of pigs that entered at the GF batch. The "total duration of GF" (TDURFAT, days) is calculated as the number of days elapsed between the entrance of the first group of pigs in the GF unit and the exit of the last group of pigs sent to the slaughterhouse. In contrast, the "average duration of GF" (ADURFAT, days) is calculated as the average number of days between the entrance in the GF unit and the exit to slaughter for different groups of pigs sent to the slaughterhouse, respectively. Culling rate (CR) represented the percentage of animals having market value lower than 100%. Causes for this devaluation may be: batch weight far from the average body weight, previous disease, poor conformation, etc. The percentage of barn occupation (BO) was calculated as the number of pigs in the barn divided by the total pig places in the barn multiplied by 100. Finally, mortality rate (MORT) was calculated as the difference between the number of growing pigs entering into the fattening house and the number of pigs sent to the slaughterhouse divided by the number of pigs that entered the GF unit multiplied by 100.

Data analysis

The dataset obtained from the survey was submitted to univariate and bivariate descriptive analysis. Des-

Table 1. Description of the variables recorded

Variable	Variable definition
General information	
YEAR	Year of placement
TRIMESTER	Trimester of placement
HERD	Type of herd
PIGFAT	Type of commercial pig produced
SPLITSEX	Split-sex in pens
GENDER	Genders presents
BREED	Breed of the sire pigs
Facilities	
AGEBARN	Age of the barn
PIGPEN	Number of pigs per pen
FLOOR	Floor conditions
FEEDER	Type of feeder
DRINKER	Type of drinker
VENT	Type of ventilation control
CS	Cooling system
Feeding	
FPHASE	Number of feed phases
FFORM	Form of the feeds
WATERSOU	Water source at the farm
WATERHIG	Water hygienization
NE	Content of net energy in each feed (kcal kg^{-1})
CP	Content of crude protein in each feed (%)
TL	Content of total lysine in each feed (%)
Health status	
ORIGIN	Number of pig origins
AUJESVAC	Number of Aujeszky's dose vaccine
CIRCOVAC	Circovirus vaccine
MYCOVAC	Mycoplasma vaccine
FREQATB	Frequency of antibiotic treatments
PATHATB	Pathways of antibiotics used
Production performance/records	
NPP	Number of pigs placed
IBW	Initial body weight (kg pig^{-1})
FBW	Final body weight (kg pig^{-1})
ADURFAT	Average duration of the fattening period (days)
TDURFAT	Total duration of the fattening period (days)
CR	Culling rate (%)
BO	Barn occupation (%)
TFI	Total feed intake (kg pig^{-1})
ADG	Average daily gain (kg pig^{-1})
FCR	Feed conversion ratio (kg kg^{-1})
MORT	Mortality rate (%)

criptive analysis of classification variables was performed through frequency study using Proc Freq of SAS (SAS Inst., Inc., Cary, NC, USA, version 9.2) for variables included in the group general information, facilities and feeding in Table 1. Farm was the experimental unit for all these variables. Descriptive analysis of continuous variables was performed through measures of central tendency (mean and median) and dispersion (standard deviation, quartiles and range). For continuous variables (productive performance) batch was the experimental unit. Bivariate analysis of continuous variables was done by Pearson correlation analysis using Proc Univariate, and Proc Corr of SAS. Bivariate analysis of continuous variables AFI, ADG, TDURFAT, FCR and MORT depending on classification variables and was done by using Proc Mixed of SAS with company as random effect and batch as experimental unit. Only company was considered as a random effect because many farms contributed to the study with only one batch of pigs, thus the random effect of farm could not be studied.

Results and discussion

Results of categorical variables describing the farms are presented in Table 2. This study included information mainly about GF farms (94.7%) including pig batches distributed during all trimesters of 2008 and 2009. According to the MAGRAMA (2011), 11% of the pig farms in Spain were classified as farrow-to-finish farms. Thus a low proportion of this type of farms was expected. Concerning farm size, the median value of NPP was 1,217 with values ranging between 233 and 6,198 pigs per batch and 80% of the farms having between 500 and 2,500 pigs per batch (Fig. 1). In Spain, it has been observed a concentration of pig producers in the last years with a decrease in the total number of GF farms and an increase in the number of pigs per farm.

The type of animal produced in each farm depends on the final objective of the producer. Spain is the world leader in production of dry-cured hams and for this purpose high final weight pigs are needed (Resano *et al*., 2007). Thus, most farms (86.7%) produced "industrial pigs" (95-110 kg at slaughtering) and 13.3% produced "heavy fat pigs" (< 110 kg). The type of pig produced is also closely related to the gender and breed of the animals used. Gender segregation in pens (49.8%), use of entire males (59.5%) and Pietrain-sire pigs (70.0%) are used to produce "light" or "industrial" pigs while mixed-sex pens, presence of barrows and White (Landrace, Large White or their commercial crossings; 19.6%) and/or Duroc-sire pigs (7.8%) are combinations used to produce "industrial" or "heavy" pigs.

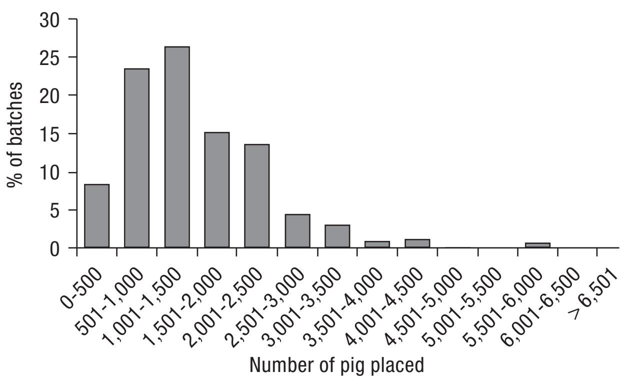

Figure 1. Distribution of the number of pigs placed per batch (764 batches).

Concerning "facilities", information about age of farms in Spain is scarce in the literature and in many cases pig farms owners do not know the real age of their farms. In the present study, 38.5% of the farms did not have reliable information about age, approximately 42% of the farms were between ten and thirty years old and only 8.2% reported to be older than 30 years. Presumably, many farms not able to report age were more than thirty years old. Most farms had pens with capacity for 13 to 20 pigs (87%), with ≥ 50% of concrete slated floor (70%) and nipple drinker (89%). However, a higher heterogeneity was found in feeder type with 54% of farms having a "single-space" dry feeder, 20.6% having this feeder with an incorporated drinker and 24.3% having a "multi-space" conventional dry feeder. Pen size has been increased in recently built GF farms due to better outputs (Penny, 2000) but a low percentage (1.1%) of pens containing more than 20 pigs was found. Both "number of pigs per pen" and "percentage of slatted floor" are important for other factors such as the temperature, density of animals, ventilation control or number of feeders and drinkers. In the last years, there was an increase in single-space feeders with an incorporated drinker in GF pig farms because they had been associated to better feed intake. In fact, multi-space feeders were normally found in older farms. Concerning environmental control, most farms (71%) had "automatic" ventilation but only 10.3% of farms had cooling systems available. In Spain, the use of automatic ventilation control and cooling systems in pig farms could be justified due the high temperatures observed between May and September.

Concerning feeding programs, most farms used three (75%) or four (24.3%) feeding phases based on pig age or weight depending on the company and almost all farms used pelleted feeds (91%). Liquid feed has been implanted in some GF farms in recent years but none of them were included in the database. Feeding programs included in this study follow FEDNA (2006)

Table 2. Characterization of the descriptive variables recorded from 452 growing-finishing pig farms

Variable	Categories
General information	
YEAR[1]	2008 (33.7%); 2009 (63.5%); 2010 (2.8%)
TRIMESTER[1]	Jan-Feb-Mar (18.3%); Apr-May-Jun (26.4%); Jul-Aug-Sep (18.1%); Oct-Nov-Dec (37.2%)
HERD	Nursery and growing-finishing (5.3%); growing-finishing (94.7%)
PIGFAT	Industrial 95-110 kg (86.7%); heavy < 110 kg (13.3%)
SPLITSEX	Mixed-sex (50.2%); single-sex (49.8%)
GENDER	Male; female and barrow (11.7%); male and female (59.5%); barrow and female (23.5%); missing (5.3%)
BREED[2]	Pietrain (69.9%); White (19.6%); Duroc (7.8%); Pietrain × White (1.3%); Others (1.3%)
Facilities	
AGEBARN	< 10 years (11.5%); between 10 and 30 years (41.8%); < 30 years (8.2%); missing (38.5%)
PIGPEN	≤ 12 pigs (9.3%); between 13 and 20 pigs (87.2%); < 20 pigs (1.1%); missing (2.4%)
FLOOR	Slatted < 50% (27.9%); slatted ≥ 50% (69.9%); missing (2.2%)
FEEDER	Multi-space (24.3%); single-space (54.0%); single space with incorporated drinker (20.6%); others (0.2%); Missing (0.9%)
DRINKER	Nipple (88.7%); bowl (6.6%); only drinker incorporated in feeder (2.7%); missing (2.0%)
VENT	Manual (27.9%); automatic (71.2%); missing (2.0%)
CS	No (87.8%); yes (10.3%); missing (1.7%)
Feeding	
FPHASE	Two (0.7%); three (75.0%); four (24.3%)
FFORM	Pellet (90.9%); meal (9.1%)
WATERSOU	Well (23.2%); river (17.7%); public water (36.5%); others (8.4%); missing (14.2%)
WATERHIG	No (37.8%); yes (55.8%); missing (6.4%)
NE[3]	Feed 1 (2;403 ± 72.68); feed 2 (2;376 ± 78.26); feed 3 (2;360 ± 57.14)
CP[3]	Feed 1 (17.12 ± 1.91); feed 2 (16.15 ± 0.72); feed 3 (15.60 ± 0.83)
TL[3]	Feed 1 (1.12 ± 0.13); feed 2 (1.10 ± 0.23); feed 3 (0.93 ± 0.08)
NE[4]	Feed 1 (2;414 ± 54.36); feed 2 (2;399 ± 41.21); feed 3 (2;419 ± 68.19); feed 4 (2;428 ± 93.82)
CP[4]	Feed 1 (17.63 ± 1.29); feed 2 (17.21 ± 0.99); feed 3 (16.63 ± 0.80); feed 4 (15.66 ± 0.95)
TL[4]	Feed 1 (1.17 ± 0.02); feed 2 (1.03 ± 0.09); feed 3 (0.96 ± 0.16); feed 4 (0.85 ± 0.16)
Health status	
ORIGIN	One origin (54.4%); two or more origins (45.6%)
AUJESVAC	One dose (11.1%); two doses (21.9%); three doses (65.3%); missing (1.7%)
CIRCOVAC	No (76.4%); yes (21.9%); missing (1.7%)
MYCOVAC	No (76.2%); yes (22.1%); missing (1.7%)
FREQATB	Until twice (37.8%); three or more times (61.3%); missing (0.9%)
PATHATB	Water (1.1%); feed (21.3%); injection (0.2%); water + feed (13.9%); feed + injection (9.1%); water + feed + injection (51.3%) missing (3.1%)

[1] Considering batches as experimental units (n = 764). [2] For "White breed" it was considered the follow breeds: Landrace or Large White or the crossing between them. [3] Means and standard deviations in each feed phase used by 555 batches belonging to 347 herds that had three feed phases at growing-finishing period. [4] Means and standard deviations in each feed phase used in 218 batches belonging to 116 herds that had four feed phases at growing-finishing period.

recommendations to some extent but they are difficult to compare because the time for each feeding phase is very different among farms. Regarding the source of drinking water, 36.5% of farms used public tap water, in approximately 23% water came from a private well, 17.7% used water from a river and 8.5% from other sources. Moreover, 56% of farms treated the drinking water on farm, in coincidence with those farms which did not use public tap water. This variable indicates indirectly the water quality used by pig farms and it could influence productive performance (Nyachoti *et al.*, 2005).

Regarding health status, the number of pig origins in each batch is a very important factor affecting health in GF farms (Maes *et al.*, 2000, 2004). In this sense, almost half of the farms (45.6%) received pigs from two or more origins. This fact may be reflecting the existence of small weaning farms not able to provide enough number of animals for a particular GF unit. All farms vaccinated their pigs against Aujeszky's disease with proximately 11, 22 and 65% of farms vaccinated one, two and three dose, respectively. However, only around 22% of farms used circovirus and mycoplasma vaccine. Aujeszky's disease vaccination is so widely used because this disease is under mandatory reporting in Spain where the eradication program started in 1995 and was adapted and reinforced in 2003 (BOE, 1995). Circovirus disease (PCV2) was firstly described in Spain in 1997 and the infection is present in almost 100% of Spanish pig farms (Sibila *et al.*, 2004). However, commercial vaccine against PCV2 was recently developed and it is starting to be used to minimize the effects of this disease in pig production. With respect to *M. hyopneumoniae*, it is the principal etiologic agent of porcine respiratory disease complex being present in pigs farms worldwide (Thacker, 2006). Vaccination is an important tool for its control enhancing performance by reducing prevalence and severity of lung lesions. However, vaccination is more often used in earlier phases and many animals may be already vaccinated once they reach GF phase. As far as the frequency of antibiotics treatment is concern, 61.3% of the farms treated three or more times the animals with some kind of antibiotic while 37.8% treated less than three times. Over half of the farms (51.3%) combined the use of feed, water and injection to administer antibiotics. This high use of antibiotics by different methods could be justified by the ban of the use of antibiotic growth promoter in the EU since 2006 causing an increase in both preventive and curative uses of antibiotics (Wierup, 2001).

Results for continuous variables describing productive performance were 19.0 ± 2.56 kg and 108.0 ± 6.20 kg for IBW and FBW, respectively, 136 ± 12 and 154 ± 17 days for ADURFAT and TDURFAT, respectively, 1.4 ± 1.23% (range 0.0 to 8.0 %) for CR, 99.7 ± 1.36% for BO, 244 ± 26.1 kg and 0.657 ± 0.0650 kg for TFI and ADG, 2.77 ± 0.178 for FCR and 4.3 ± 2.64% (range 0.0 to 16.5%) for MORT. This results were similar to those published by the Observatori del Porcí (2012) assessing the main performance parameters in around 12,475,503 GF pigs from Spain during 2011 with average values of: 18.3 and 105.0 kg for IBW and FBW, respectively, 131.5 days for ADURFAT, 229.17 kg for TFI, 0.662 kg for ADG, 2.66 for FCR and finally 3.7% for MORT. Table 3 shows the values of these variables for both industrial and heavy pig farms. All values were different between both types of pigs except for mortality. Heavy pigs had a 3.6% shorter ADURFAT

Table 3. Comparison of the main continuous variables registered between "industrial" (I) and "heavy" (H) fattening pigs through univariate statistical analysis[1]

Variable[2]	Fattened pig[3]	n	Mean	Std	Min	1st quartile	Median	3rd quartile	Max
ADURFAT	I	649	137[b]	12.7	90	128	135	145	178
	H	111	132[a]	9.8	110	125	131	139	155
TDURFAT	I	652	153[a]	16.9	99	143	155	164	203
	H[4]	29	174[b]	14.5	147	165	170	184	205
TFI	I	653	237[a]	20.0	176	223	236	250	310
	H	111	287[b]	14.8	231	278	287	296	358
ADG	I	649	0.641[a]	0.051	0.503	0.605	0.638	0.676	0.804
	H	111	0.753[b]	0.058	0.618	0.720	0.758	0.789	0.936
FCR	I	653	2.74[a]	0.172	2.28	2.62	2.71	2.84	3.43
	H	111	2.93[b]	0.115	2.71	2.86	2.93	3.01	3.23
MORT	I	653	4.3	2.7	0.0	2.4	3.6	5.4	16.5
	H	111	4.5	2.2	0.8	2.9	4.2	5.9	12.2

[1] Means in the same column and variable superscripted with different letters were significant ($p < 0.001$). [2] I (final body weight ranged from 95 to 110 kg); H (final body weight higher than 110 kg). [3] Variables: ADURFAT (average duration fattening period, days); TDURFAT (total duration fattening period, days); TFI (total feed intake, kg pig^{-1}); ADG (average daily gain, kg pig^{-1}); FCR (feed conversion ratio, kg kg^{-1}); MORT (mortality rate, %). [4] Missing values were due to a company which did not provide information about TDURFAT.

Table 4. Pearson correlation coefficients for all production performance recorded in batches from "industrial" growing-finishing pigs[1]

Variables[2]	IBW	FBW	ADURFAT	TDURFAT	CR	BO	TFI	ADG	FCR	MORT
IBW	1	—	—	—	—	—	—	—	—	—
FBW	–0.06	1	—	—	—	—	—	—	—	—
ADURFAT	–0.60***	0.27***	1	—	—	—	—	—	—	—
TDURFAT	–0.24***	0.01	0.57***	1	—	—	—	—	—	—
CR	–0.11*	–0.07	0.24***	0.32***	1	—	—	—	—	—
BO	–0.13***	0.14***	0.17***	–0.11***	–0.27***	1	—	—	—	—
TFI	–0.24***	0.71***	0.45***	0.27***	0.20***	0.02	1	—	—	—
ADG	0.30***	0.33***	–0.77***	–0.60***	–0.30***	–0.05	0.01	1	—	—
FCR	0.21***	0.14***	0.12***	0.28***	0.34***	–0.16***	0.70***	0.14***	1	—
MORT	0.01	–0.03	0.13***	0.41***	0.39***	–0.16***	0.29***	–0.18***	0.53***	1

[1] *** $p < 0.01$, ** $p < 0.05$. [2] Variables: IBW (initial body weight, kg pig^{-1}); FBW (final body weight, kg pig^{-1}); ADURFAT (average duration fattening period, days); TDURFAT (total duration fattening period, days); CR (culling rate, %); BO (barn occupation, %); TFI (total feed intake, kg pig^{-1}); ADG (average daily gain, kg pig^{-1}); FCR (feed conversion ratio, kg kg^{-1}); MORT (mortality rate, %).

and a 12% longer TDURFAT, and had higher TFI (17.4%), ADG (14.9%), and FCR (6.5%) than "industrial" pigs. Because of these differences between industrial and heavy pigs, bivariate descriptive analysis results are presented in Tables 4 and 5 only for industrial pigs in order to avoid confounder effects.

Correlation analysis between continuous variables (Table 4) showed strong correlations (absolute values ≥ 0.60 and $p < 0.01$) among IBW-ADURFAT (–0.60), FBW-TFI (0.71), ADURFAT-ADG (–0.77), TDURFAT-ADG (–0.60) and TFI-FCR (0.70). Most of these correlations may be expected, such as the correlation between feed intake and the duration of the GF period or the fact that IBW, and not FBW, is correlated to ADURFAT. In the other hand, the weakest correlations (absolute values ≤ 0.05 and $p < 0.05$) were observed between IBW-MORT (0.01), FBW-TDURFAT (0.01), FBW-MORT (–0.03), BO-TFI (0.02), BO-ADG (–0.05) and TFI-ADG (0.01). These low correlations are mostly due to a narrow distribution of variables as FBW or BO. For IBW-MORT the result may be not expected since the initial weight of the animals entering the GF unit does suppose a health challenge for the pigs (Larriestra *et al.*, 2005).

Table 5 shows descriptive bivariate analysis of TFI, ADG, TDURFAT, FCR and MORT depending on classification factors. Pigs that grew during summer period (placed between April and June) presented ($p < 0.01$) lower values of TFI, ADG, FCR and MORT compared to those which grew in the winter period (placed between October and December). These results agree with the study published by Oliveira *et al.* (2009) in Spain and Maes *et al.* (2004) in Belgium. Both studies obtained lower mortality rates in batches housed between May and August. According to Maes *et al.* (2004), barn windows are usually closed in cold periods in order to keep temperature leading to an accumulation of gases that can be harmful for the animals due to poor ventilation. Furthermore, pigs may reduce feed intake in warm periods in order to reduce body heat production depending mainly on environmental conditions inside the barns and diet composition. In our study, diet composition was not adjusted to environmental conditions and it may explain the TFI reduction. Concerning farm size, batches with less than 800 pigs presented ($p < 0.01$) higher ADG and lower TDURFAT and MORT with no changes in TFI. Maes *et al.* (2004) also found a lower mortality in batches containing less number of pigs (with farms ranging from 65 to 1288 pigs) and Oliveira *et al.* (2007) found better ADG in small batches (≤ 400 pigs *vs.* < 400 pigs) but Oliveira *et al.* (2009) registered no effect on MORT (<400 pigs; 400-600 pigs; <600 pigs). Small herds may allow performing an easier all in/all out management with animals from one origin improving health status.

As discussed above, split-sex pens, gender and breed of the sire pigs were only found as factors in particular combinations because they are not selected in an independent way. Thus, these three variables were combined and presented as a single variable in Table 5 in order to avoid a confounding effect. Combinations "barrow and female + mixed-sex + White breeds" and "barrow and female + mixed-sex + Duroc breed" showed

Table 5. Associations between predictor variables (production factors) and the main outcome variables (productive performance, mean ± SE) in batches from "industrial" growing-finishing pigs. Company was included as random effect and categorical variables which were not significant ($p < 0.10$) for any variable are not shown[1]

Variable level	n	TFI	ADG	TDURFAT	FCR	MORT
Trimester of placement		***	***	**	***	***
Jan-Feb-Mar	109	233 ± 3.7^{b}	0.634 ± 0.012^{b}	152 ± 6.2^{a}	2.75 ± 0.039^{ab}	4.8 ± 0.57^{a}
Apr-May-Jun	185	226 ± 3.6^{c}	0.626 ± 0.011^{b}	149 ± 6.1^{ab}	2.70 ± 0.038^{b}	3.5 ± 0.56^{b}
Jul-Aug-Sep	111	243 ± 3.8^{a}	0.659 ± 0.012^{a}	151 ± 6.2^{ab}	2.75 ± 0.039^{ab}	4.4 ± 0.58^{a}
Oct-Nov-Dec	248	240 ± 3.6^{a}	0.660 ± 0.011^{a}	148 ± 6.1^{b}	2.78 ± 0.038^{a}	4.8 ± 0.56^{a}
Number of pigs placed			***	***		***
< 800 pigs	146	234 ± 3.5	0.656 ± 0.011^{a}	141 ± 6.3^{c}	2.73 ± 0.039	3.9 ± 0.56^{b}
800-2,000 pigs	348	235 ± 3.3	0.643 ± 0.011^{b}	152 ± 6.2^{b}	2.75 ± 0.038	4.5 ± 0.54^{a}
< 2,000 pigs	159	238 ± 3.5	0.636 ± 0.011^{b}	156 ± 6.3^{a}	2.77 ± 0.039	4.8 ± 0.56^{a}
Gender/Split-sex/Breed[2]		***	***		***	
M, F, B + SS + P	100	246 ± 6.9^{ab}	0.591 ± 0.027^{c}	155 ± 20.9	2.70 ± 0.073^{bc}	2.8 ± 1.44
M, F + SS + P	243	226 ± 4.9^{c}	0.655 ± 0.020^{abc}	154 ± 14.8	2.65 ± 0.052^{c}	4.0 ± 1.02
M, F + MS + P	180	229 ± 3.4^{c}	0.644 ± 0.013^{bc}	149 ± 9.4	2.74 ± 0.035^{bc}	4.6 ± 0.68
M, F + MS + W	24	241 ± 4.8^{b}	0.664 ± 0.016^{ab}	146 ± 9.8	2.87 ± 0.045^{ab}	5.2 ± 0.83
B, F + MS + W	53	253 ± 4.1^{a}	0.678 ± 0.014^{a}	147 ± 9.6	2.92 ± 0.040^{a}	4.8 ± 0.75
B, F + MS + D	24	242 ± 4.8^{b}	0.674 ± 0.016^{a}	143 ± 9.8	2.88 ± 0.046^{a}	4.1 ± 0.83
Number of pigs per pen				***		
≤ 12 pigs	76	236 ± 4.2	0.655 ± 0.012	145 ± 6.2	2.73 ± 0.043	3.9 ± 0.60
13-20 pigs	549	235 ± 3.4	0.644 ± 0.011	150 ± 5.9	2.75 ± 0.038	4.4 ± 0.51
Age of the building		*	***	***		*
< 10 years	84	233 ± 4.2^{b}	0.640 ± 0.013^{b}	150 ± 6.5a	2.73 ± 0.043	4.1 ± 0.63
10-30 years	298	235 ± 3.9^{ab}	0.641 ± 0.012^{b}	150 ± 6.4a	2.76 ± 0.040	4.6 ± 0.59
< 30 years	61	242 ± 4.5^{a}	0.665 ± 0.013^{a}	142 ± 6.6b	2.77 ± 0.045	4.0 ± 0.66
Floor			*			
< 50% slatted	220	237 ± 3.5	0.649 ± 0.011	149 ± 5.8	2.75 ± 0.038	4.4 ± 0.54
≥ 50% slatted	413	234 ± 3.5	0.641 ± 0.011	150 ± 5.8	2.74 ± 0.038	4.4 ± 0.54
Ventilation		**			**	*
Manual	235	239 ± 3.4	0.641 ± 0.012	149 ± 5.9	2.78 ± 0.036	4.7 ± 0.53
Automatic	408	233 ± 3.2	0.648 ± 0.012	150 ± 5.9	2.72 ± 0.035	4.1 ± 0.50
Number of animal origins				***	**	***
One origin	386	234 ± 3.3	0.647 ± 0.011	148 ± 5.9	2.74 ± 0.034	4.0 ± 0.47
Two or more origins	267	237 ± 3.4	0.641 ± 0.012	153 ± 6.0	2.77 ± 0.035	5.1 ± 0.49
Circovirus vaccine		***		***	***	***
No	481	238 ± 3.8	0.649 ± 0.012	148 ± 6.5	2.76 ± 0.043	4.5 ± 0.67
Yes	157	219 ± 4.2	0.645 ± 0.013	143 ± 6.6	2.65 ± 0.046	2.3 ± 0.71
Frequency of antibiotics use						*
Until twice	234	233 ± 4.1	0.643 ± 0.013	148 ± 6.1	2.72 ± 0.045	3.8 ± 0.56
Three or more times	410	238 ± 4.0	0.644 ± 0.012	150 ± 6.0	2.77 ± 0.044	4.9 ± 0.55
Pathways of antibiotic use			*	***		**
Feed	170	239 ± 4.9	0.658 ± 0.019	135 ± 6.9^{b}	2.76 ± 0.051	3.3 ± 0.64^{b}
Water + feed	123	235 ± 5.2	0.640 ± 0.019	146 ± 7.0^{a}	2.73 ± 0.053	3.9 ± 0.68^{ab}
Water + feed + injection	325	236 ± 5.5	0.632 ± 0.022	164 ± 7.9^{a}	2.79 ± 0.058	5.7 ± 0.72^{a}
Water source				***		***
Well	106	234 ± 4.4	0.645 ± 0.015	149 ± 6.1^{a}	2.71 ± 0.045	3.5 ± 0.39^{b}
River	109	235 ± 4.2	0.649 ± 0.015	147 ± 6.0^{a}	2.73 ± 0.045	4.5 ± 0.37^{a}
Public water	258	233 ± 3.7	0.652 ± 0.014	143 ± 5.9^{b}	2.72 ± 0.042	3.7 ± 0.29^{b}
Others	59	233 ± 4.5	0.662 ± 0.015	139 ± 6.1^{b}	2.72 ± 0.046	3.4 ± 0.41^{b}

[1] * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. Levels from the variables that contained less than 10 batches were excluded of this table. Means in the same column and variable superscripted with different letters were significant ($p \leq 0.05$). [2] Gender: M, F, B (male, female and barrow); M, F (male and female); B, F (barrow and female). Split-sex: SS (single-sex); MS (mixed sex). Breed of the sire pigs: P (Pietrain); W (White); D (Duroc).

the highest TFI, ADG showing also the worst FCR. According to Wise *et al.* (1996) productive efficiency depends on gender, age and body weight of pigs being barrows generally considered less efficient than females which are less efficient than entire males. Sex segregation in pens is also considered as a good method to improve efficiency (Niemi *et al.,* 2010). Finally Edwards *et al.* (2006) found that Duroc-sired pigs had a higher body weight, ADG and backfat thickness than Pietrain pigs, and it is known that Pietrain-sired pigs are more efficient than other breeds by expressing a higher lean tissue growth (Gispert *et al.*, 1997). Thus combinations including mixed barrows and females with no Pietrain genetics were expected to be the least efficient ones.

Concerning facilities, pigs allocated in small pens (< 12 pigs) presented ($p < 0.01$) lower TDURFAT than those in pens containing between 13 and 20 pigs. Published studies relating the number of pigs per pen over performance considered a small pen with at most 20 pigs and a big pen with at least 50 pigs (Turner *et al.*, 2000). These authors found higher body weight gain in small pens compared to big pens. Both categories used for pen size in the present study, pens with less than 13 pigs and those containing between 13 and 20 pigs, were considered "small" by those authors and maybe the lack of differences is just a lack of data range. A higher TFI ($p = 0.06$) and ADG ($p < 0.01$) and a lower TDURFAT ($p < 0.01$) was observed in older than in newer barns despite the large number of missing values registered for this variable (38.5%). Older barns used to be smaller and were associated to a greater degree of precariousness in building conditions and characteristics of facilities. However, improvements applied to facilities were not considered in the current studies. A better assessment of the age of facilities and its status should be included in future studies.

Pigs placed in pens with < 50% of slated floor tended to have a higher ADG ($p = 0.08$) compared to those containing ≥ 50%. Oliveira *et al.* (2009) and Averós *et al.* (2010) neither found any influence of the percentage of slated floor on TFI or MORT. Percentage of slated floor is related to health problems caused mainly by the ammonia concentration. Ye *et al.* (2009) observed lower ammonia concentration and better air quality in partial slat pens than those with total slat and Aarnink *et al.* (1997) stated that decreasing the percentage of slated floor from 50 to 25% reduced the ammonia level by 11%. Partial slat may also help pigs to better define specific areas for resting allowing them to rest in a dry, solid floor (Hacker *et al.,* 1994). A lower TFI ($p = 0.02$), FCR ($p < 0.01$) and MORT ($p = 0.07$) with no change in ADG or TDURFAT was observed in pigs placed in barns equipped with an automatic ventilation system compared to those with manual system. Results emphasize the importance of the ventilation system in pig's thermal sensation, as improving thermal comfort increases performance (Choi *et al.*, 2010). Moreover, according to Wathes (1994), ventilation system is the most efficient method to reduce the concentration of inside barn air pollutants.

Concerning health status variables, batches that were filled with pigs from just one farm origin had lower TDURFAT ($p < 0.01$), FCR ($p = 0.04$) and MORT ($p < 0.01$) compared to those from two or more origins. Results from this study agree with some previous studies which observed the effects of the number and/or type of pig origins on mortality (Maes *et al.*, 2000, 2004; Oliveira *et al.*, 2007, 2009). According to Maes *et al.* (2000), there are specific pathogen sources in each origin farm and thus a mixture of pathogens and immunity status may occur in a GF batch with multiples origins, increasing the risk of disease and reducing performance. Vaccination was also an important health related factor. Batches which performed commercial circovirus vaccine in their pigs presented ($p < 0.01$) lower values for TFI, TDURFAT, FCR and MORT compared to those that did not. This reduction in mortality and the improvement in feed efficiency in vaccinated pigs also were observed by Segales *et al.* (2009) and Jacela *et al.* (2011). Batches that received two antibiotics treatments or less during the GF period tended ($p = 0.07$) to have a lower MORT than batches that were treated three or more times. Moreover, it was observed a higher ($p = 0.09$) ADG and a lower TDURFAT ($p < 0.01$) and MORT ($p = 0.04$) in batches which received the antibiotics only through the feed than those in which they were administrated also through water and/or injection. It was not possible to obtain detailed information about the type of antibiotics used as well as the purpose of their use. Farms assessed in the present study did not use antibiotics as growth promoter because of their ban in the European Union in 2006. However, according to Wierup (2001), banning the use of antibiotic growth-promoters in animal feeds is often associated to an increase in both preventive and curative use of antibiotics. Probably, the better productive performance found in batches receiving only in-feed medication was due to a preventive use of antibiotics whereas water and injection medications were used more for curative purposes (Miller *et al.*, 2003). In any case, these results show that batches treated more times with antibiotics are related to poorer health status. Antibiotic treatment could be used as a monitoring parameter, and those farms using antibiotics three or more times in different consecutive batches may be worth to explore for possible alternatives strategies.

Finally, batches belonging to farms that obtained the drinking water from "public water supply" and "other" sources presented lower TDURFAT ($p < 0.01$) and those that obtained it from a river had higher MORT ($p < 0.01$) in comparison to other ones. Patience (1989) stated that poor water quality can impair health, reduce productivity and cause death in severe cases, leading to poor pig welfare and economic losses for the producer. Vico *et al.* (2011) observed that pig farms supplied with water sources that were not derived from "public supply" had higher level of contamination by *Samonella* in GF pigs, although the authors did not assess effects on productive performance. These differences can be justified by the chloride treatment that normally is performed to public water before its consumption.

In conclusion, the results showed that many of the production factors studied did affect performance, although some others which were not taken into account in the current study may also do so. The influence of some production factors were highly significant (*e.g.* trimester of placement, ventilation system and circovirus vaccination) and data can help to quantify their effects. However, other parameters (*e.g.* type of feeder or drinker, frequency of antibiotic use and fraction of slated floor) did not show significant effects over productive performance. Furthermore, some not expected results were found, as the effect of the number of pigs placed, favouring small farms, over both the total duration of the fattening period (differences up to two weeks) and the mortality rate (differences up to 19%) or the number of animal origins affecting almost exclusively the mortality rate (about 22% of difference between the levels). These data contribute to better describe the current situation of the Spanish GF pig production and will be a useful tool for future analysis and studies.

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